THE STRUCTURE AND CLASSIFICATION OF THE LOWER GREEN ALGAE

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WITH ONE PLATE

In a paper entitled The Structure and Classification of the Phycomycetes, published in the *Transactions* of the American Microscopical Society, Volume XXIV, the characters of the second branch or phylum (Phycophyta) of the vegetable kingdom were given. Its two classes (Chlorophyceae and Phaeophyceae) were separated by diagnostic characters, and the former rather fully described, and in turn separated into four orders. The present paper deals with the organisms falling under the lowest of these orders, *viz*: the Protococcoideae. In order that the place of the plants here described may be fully understood, I have revised some of the paragraphs of the paper referred to, and included them in the present article.

PHYLUM II—**PHYCOPHYTA**

Phycophytes; Spore Tangles

Plants consisting of single cells, filaments, or masses, free or attached by rhizoids: reproducing asexually (propagation) by fission of the whole plant, or some of its parts, or by zoopores; and sexually (generation) by the union of two protoplasts (gametes) to form a single spore (zygote) which is often a resting-spore. (Sexual reproduction is known for only a small number of species, but so far as known it conforms to the type here indicated.) There are two classes, Chlorophyceae and Phaeophyceae, the former of green plants, the latter of brown or olive-green plants.

Class **CHLOROPHYCEAE**

Green Algae

Plant-body from microscopic single cells to simple or branched filaments, and large multinucleate, branching coenocytes, more

rarely flat masses or plates of cells: cells typically containing chlorophyll, and therefore bright green, sometimes obscured by phycoxanthin and then yellowish or brownish. There are four orders.

KEY TO THE ORDERS.

A. Plants all unicellular; generation planogametic, *Protococcoideae.*

B. Plants filamentous or stratose; generation from planogametic isogamy to gynogametic heterogamy, *Confervoideae.*

C. Plants filamentous (or unicellular by solution); generation aplanogametic, *Conjugatae.*

D. Plants tubular or spheroidal, coenocytic; generation from planogametic isogamy to gynogametic heterogamy, *Siphoneae.*

Order PROTOCOCCOIDEAE

Green Slimes

Plants microscopic, unicellular, but sometimes aggregated into definite and regular colonies, green (except in the hysterophytes), with mostly parietal chloroplasts, occasionally concealed in old plants by a red pigment; propagation by cell-division, zoospores, and the formation of agamic thick-walled resting spores (chlamydospores); generation by the union of equal motile gametes (isogametes), or of unequal motile gametes (heterogametes), or of antherozoids with oospheres resulting in the formation of a single spore (zygote). In many species the vegetative cells, or even the zoospores (after losing their cilia) divide repeatedly within a gelatinous mass, and then constitute the "Palmella stage," formerly supposed to be distinct genera, *e. g., Palmella, Gloeocystis,* etc. Many cells of Protococcoideae contain one or more contractile vacuoles.

KEY TO THE FAMILIES.

A. Vegetative cells not ciliated,
  I. Cells single, or in loose irregular colonies, or in gelatinous masses,
    a. Cells containing chlorophyll,
      1. Not forming zoospores, *Pleurococcaceae.*
      2. Forming zoospores, *Protococcaceae.*
    b. Cells without chlorophyll, *Synchytriaceae.*
  II. Cells aggregated into regular colonies, *Hydrodictyaceae.*

B. Vegetative cells ciliated (doubtful plants), *Volvocaceae.*

The family Synchytriaceae, composed of colorless plants (fungi), has been fully discussed elsewhere and will be omitted here (*cf.*

The Structure and Classification of the Phycomycetes, *Trans. Am. Mic. Society,* Vol. XXIV, pp. 31–33).

Family Pleurococcaceae

Cells spherical. elliptical or falcate, green, single, or after division remaining attached to form loose colonies; sometimes imbedded in a gelatinous mass, or rarely stalked. Propagation merely by fission, the daughter cells separating at once, or remaining attached; often being retained within the wall of the mother cell for some time. Propagation by zoospores unknown. Generation unknown.

Key to the Genera.

A. Cells not imbedded in gelatine, nor on gelatinous stalks,	
I. Cells single, or loosely united in indefinite numbers,	
a. Cells spherical, smooth,	
1. Cells small, chromatophores few or one,	1. *Pleurococcus.*
2. Cells large, chromatophores numerous,	2. *Eremosphaera.*
b. Cells spherical, aculeate,	3. *Trochiscia.*
c. Cells oval,	4. *Nephrocytium.*
d. Cells falcate,	5. *Ankistrodesmus.*
II. Cells loosely united in definite numbers, in one plane,	6. *Crucigenia.*
B. Cells imbedded in gelatine,	7. *Schizochlamys.*
C. Cells on gelatinous stalks,	8. *Dimorphococcus.*

The relationships of these genera may be shown by the following scheme.

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                       6. Crucigenia
8. Dimorphococcus           |
       |          5. Ankistrodesmus
7. Schizochlamys            |
       |           4. Nephrocytium
       |                    |     3. Trochiscia
       |                    |          |     2. Eremosphaera
       |___________1. Pleurococcus_____|___________|
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1. *Pleurococcus* Meneghini. Cells globose, or angled by mutual pressure, solitary, or in small, free-floating families of two to thirty-two, wall thin, smooth, green (chromatophores several or one, parietal), or partly or wholly obscured by or changed to red.—On moist surfaces, and in water, forming a green layer. Cells variable, from 2 or 3 μ (6 to 8 μ commonly) to 25 or 30 μ in diameter.

2. *Eremosphaera* DeBary.[1] Cells large, single, free-floating,

[1] This genus was named *Chlorosphaera* by Henfrey in 1859, but as DeBary's name was given in 1858 that must stand, while Henfrey's falls into synonymy. It is, therefore, not available for further use. (See *Smaragdina.*)

spherical, with numerous chromatophores, which are parietal, or rayed from the center of the cell; wall smooth.—Species one, in swamps and lakes. Cells 100 to 150 μ (rarely 30 to 80 μ) in diameter.

3. *Trochiscia* Kuetzing. Cells globose, or subglobose, mostly solitary, wall thick, aculeate.—In fresh or brackish waters. Cells 9 or 10 μ (20 or 30 μ commonly) to 80 or 90 μ in diameter.

4. *Nephrocytium* Naegeli. Cells oblong, reniform, green, two, four, eight or sixteen floating free within a thin, bladder-like membrane, the whole colony free-swimming.—In quiet fresh waters. Cells in one species 2 to 7 μ wide, in the other 11 to 22 μ, and from two to six times as long.

5. *Ankistrodesmus* Corda. (*Rhaphidium* Kuetzing.[1]) Cell acicular, fusiform or cylindrical straight or curved, the ends generally very gradually cuspidate or acuminate, solitary or in clusters, free-swimming, green.—In quiet fresh waters. Cells 1 to 7 μ in diameter (sometimes less), and many times (3 or 4 μ to 20 or 30 μ) longer.

6. *Crucigenia* Morren. (*Staurogenia* Kuetzing.[2]) Cells subquadrate, four, eight or sixteen, united into minute, tabular or hollow-cubical colonies by jelly, but not enclosed in a membrane.—In fresh waters. Cells 4 to 10 μ in diameter, the colonies from 13 to 55 μ.

7. *Schizochlamys* A. Braun. Cells globose or elliptical, pale green or yellowish, to brownish, solitary, or two to four in a gelatinous family, the surrounding membrane at length splitting into two or four parts.—In stagnant water. Cells 11 to 14 μ in diameter.

8. *Dimorphococcus* A. Braun. Cells of two forms—(1) obtuse-ovate, oblique, (2) lunate,—connected by gelatinous threads into botryoid, free-swimming families.—In quiet waters. Cells 4 to 8 μ long, and half as wide.

Family Protococcaceae

Cells spherical, elliptical, or long cylindrical, green, single or loosely united into colonies, free, stalked, or imbedded in more or less regular masses of gelatine. Propagation (1) by the formation of zoospores, also, in some genera, (2) by fission, the daughter cells

[1] It appears that Kuetzing's name, which bears date of 1845, is antedated by Corda's, which was published in 1835, necessitating the change here indicated.

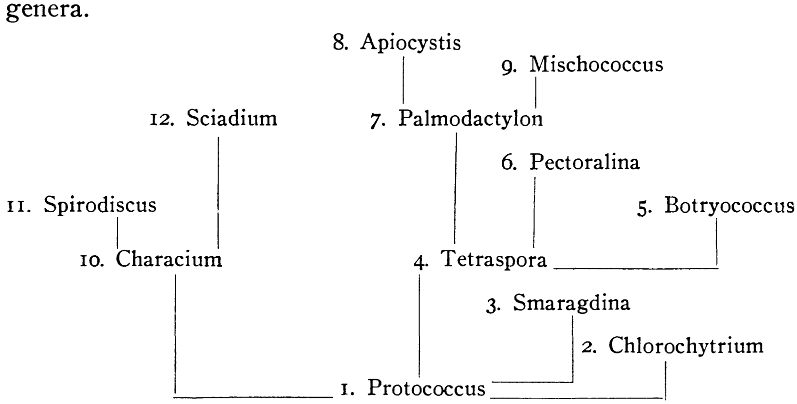
[2] Here again Kuetzing's name, first applied in 1849, is antedated. Morren's name was published in 1830, and must supplant that given by Kuetzing.

remaining within the mother-cell wall or attached to it. (A Pamella-stage is often present.) Generation, where known, by the union of equal or unequal biciliate gametes formed by the internal division of vegetative cells.

KEY TO THE GENERA.

A. Cells spherical or elliptical, not truly stalked,	
I. Separate, or merely aggregated,	
a. Spherical and free living,	1. *Protococcus.*
b. Spherical or elliptical, endophytic,	2. *Chlorochytrium.*
II. Imbedded in gelatinous masses,	
a. Masses of indefinite shape,	
1. Cells not in fours, irregularly massed,	3. *Smaragdina.*
2. Cells usually in fours, in one layer,	4. *Tetraspora.*
b. Masses spherical,	
1. Cells elliptical, sessile,	5. *Botryococcus.*
2. Cells spherical, with false stalks,	6. *Pectoralina.*
c. Masses cylindrical,	7. *Palmodactylon.*
d. Masses pyriform, attached,	8. *Apiocystis.*
B. Cells stalked,	
I. Cells spherical, on dichotomous stalks,	9. *Mischococcus.*
II. Cells oval or ovate, single,	10. *Characium.*
III. Cells cylindrical, umbellate,	12. *Sciadium.*
C. Cells long-cylindrical, curved, free,	11. *Spirodiscus.*

The following scheme shows the mutual relationships of these genera.



1. *Protococcus* Agardh. (*Chlorococcum* Fries.[1]) Cells globose, solitary, or aggregated, sometimes surrounded by jelly, wall thin,

[1] It is fortunate that Agardh's name, which he applied in 1824, antedates *Chlorococcum* of Fries, which bears the date of 1825.

smooth, green, chromatophore one, almost a hollow sphere, in some species partly or wholly obscured by or changed to red.—On moist surfaces, as rocks and tree trunks, and in water, forming a green layer. Cells variable, from 2 or 3 μ (10 to 12 μ commonly) to 25 μ (or rarely 100 μ) in diameter.

2. *Chlorochytrium* Cohn. Cells globose, ovoid, or reniform, green, solitary or gregarious, chromatophore one, almost a hollow sphere.—Living in the intercellular cavities of aquatic plants, *e. g.*, *Lemna*. Cells about 100 μ in diameter.

3. *Smaragdina* Bessey. (*Chlorosphaera* Klebs (1883), not of Henfrey (1859) which is *Eremosphaera* DeBary 1858.[1]) Cells spherical, single, or in irregular gelatinous masses; chromotophore one, parietal, star-shaped or reticulated; vegetative increase by the cross-partition of cells, often within the wall of the mother cell; propagation by biciliate swarmspores arising eight or more within the mother cell; generation unknown.—Species few, in fresh water or in the intercellular spaces of water plants. Cells variable, 2 or 4 μ (commonly 7 to 18 μ) to 30 μ in diameter.

4. *Tetraspora* Link. Cells globose or angled, green, usually arranged in tetrads in the gelatinous substance of the walls, and constituting large families (1 to 30 cm. long) of definite outline, not enclosed in a membrane, at first attached, afterwards floating free.—In quiet waters. Cells 2 to 17 μ in diameter.

5. *Botryococcus* Kuetzing. Cells ovoid, elliptical, olive-green, brownish or orange, walls thin, connected by gelatinous mucus into free floating or terrestrial botryoid families, each surrounded by a thin diffluent membrane.—In quiet waters and on moist earth. Cells 10 to 15 μ long, and half as wide.

6. *Pectoralina* Turpin. (*Dictyosphaerium* Naegeli, not of Decaisne.[2]) Cells oblong, oval or reniform, green, with thick walls which are confluent into a homogeneous investing jelly, each cell at

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[1] Here we have one of those unfortunate cases in which a genus is found to have no legitimate name. In 1883 Klebs applied to this organism the very appropriate name *Chlorosphaera*, but this name had already been used by Henfrey (in 1859) for another genus, and is, therefore, not available in the present instance. The name which I propose, *Smaragdina* (Greek, *smaragdos*, emerald) is suggested by its beautiful emerald-green color. The species are *S. angulosa*, *S. alismatis* and *S. entophyta*.

[2] Naegeli's name, applied in 1849, is inapplicable, since it was used for another genus by Decaisne in 1842. Reinsch's name, *Actidesmium*, appears to be antedated by *Pectoralina* of Turpin, 1828, as pointed out by Kuntze.

the extremity or side of a slender branching thread (remains of the wall of the mother cell), the whole family free-floating and surrounded by a delicate membrane.—In quiet fresh waters. Cells 3 to 20 μ long, and usually somewhat narrower.

7. *Palmodactylon* Naegeli. Cells globose, dull green, many enclosed in a cylindrical membrane, several of the latter connected at a common point, radiating and free-floating.—In stagnant ponds. Cells from 4 to 12 μ in diameter, the cylindrical families from 30 to 60 μ broad, and four to five times as long.

8. *Apiocystis* Naegeli. Cells globose, green, many enclosed in a stipitate pyriform membrane, the colony (0.2 to 1 mm. in diameter) attached.—In quiet pools of fresh water. Cells 6 to 8 μ in diameter, and from one to two in the smaller families to many hundreds in the larger.

9. *Mischococus* Naegeli. Cells spherical, two to four together in a line at the ends of thin, mostly dichotomously branched stalks which consist of the empty terminally swollen walls of earlier cells; chromatophores two to four (rarely one).—Species one, attached to other plants in fresh water. Cells 4.5 to 9 μ in diameter.

10. *Characium* A. Braun. Cells oblong, ovate, fusiform or pyriform, solitary, always attached to other plants, usually stipitate, light green.—In quiet fresh waters attached to the stems of flowering plants and algae. Cells 7 to 10 μ in diameter, and two to three times as long.

11. *Spirodiscus* Eichwald. (*Ophiocytium* Naegeli.[1]) Cells at first cylindrical and straight, afterwards variously curved, sigmoid, ringed, or even coiled, the ends rounded, mucronate or spinose, free-floating, pale green; chromatophores several, in parietal plates.—In fresh-water ponds. Cells 3 to 12 μ in diameter, and from three to ten times as long.

12. *Sciadium* A. Braun. Cells at length cylindrical, straight, green, arranged in compound, umbellate families; lower cell usually attached, bearing upon its summit a whorl of cells, each of which may bear a similar whorl of cells, which again may bear still smaller cells. The zoospores escape from the summit of the cell and attach themselves there in a whorl, growing into cylindrical cells.—In quiet

[1] *Ophiocytium,* proposed in 1849, being antedated by *Spirodiscus,* proposed in 1847, must give way to the latter. The species are *S. major, S. parvulus, S. circinatus, S. cochlearis* Eichwald, *S. capitatus.*

fresh waters, usually attached to algae and other aquatic plants. Cells 3 to 7 μ in diameter, and many times (ten or twelve) longer.

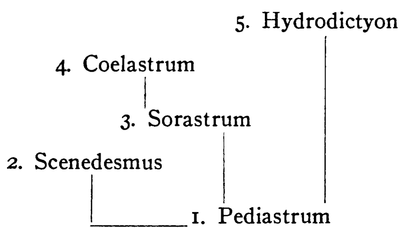
Family Hydrodictyaceae

Cells angled, ovate, elliptical, fusiform, or long cylindrical, uninucleate or multinucleate, green, combined into colonies of definite shape. Propagation by the internal formation of biciliate or non-motile swarmspores (zoospores) which join within the cell to form a colony similar to the mother colony. Generation, where known, by the union of two equal biciliate gametes. The resulting zygotes become non-motile, and eventually form two to five swarmspores which soon lose their cilia, become thick-walled and angled or lobed (" Polyedrium stage," formerly supposed to be distinct genera, *e. g. Polyedrium, Tetraedron,* etc.) Later these form swarmspores which combine into new colonies.

Key to the Genera.

A. Cells in flat families,	
1. Cells many, angled by pressure,	1. *Pediastrum.*
2. Cells usually four, oval or fusiform,	2. *Scenedesmus.*
B. Cells in sub-globose families,	
1. Families solid,	3. *Sorastrum.*
2. Families hollow,	4. *Coelastrum.*
C. Cells in cylindrical hollow reticulated families,	5. *Hydrodictyon.*

The relationships of these genera are shown by the following scheme.



1. *Pediastrum* Meyen. Cells angled, aggregated into flat, rounded families of four, eight, sixteen, thirty-two or sixty-four, which are green and free-swimming, marginal cells commonly lobed.—In bogs and pools. Cells from 2 to 20 or 25 μ in diameter, the families 25 to 120 μ.

2. *Scenedesmus* Meyen. Cells fusiform, oblong or ovoid, aggregated into flat families of two to sixteen, often mucronate or spinose,

bright green.—In stagnant fresh waters, especially on the glass sides of aquaria. Cells 4 to 6 μ in diameter, and 12 to 22 μ long.

3. *Sorastrum* Kuetzing. Cells subglobose, more or less cuneate by pressure, apex sinuate-emarginate or bifid, green, yellowish, or brownish, uninucleate, four, six, eight, sixteen or thirty-two, aggregated into globose, solid, free-swimming families.—In quiet fresh waters. Cells 10 to 15 μ in diameter, the families 16 to 60 μ.

4. *Coelastrum* Naegeli. Cells globose, or by pressure more or less angled, green, aggregated into globose, hollow, free-swimming families.—In quiet pools and ponds. Cells 4 to 18 μ in diameter, the families 20 to 90 μ.

5. *Hydrodictyon* Roth. Cells (coenocytes) cylindrical, plurinucleate, green, jointed at their ends into tubular, free-swimming nets.—In stagnant or slow-moving fresh waters. Cells in young families 1 to 2 mm. long (or less), in old families 4 to 10 mm., and from 1 to 2 mm. in diameter, the families from no more than 1 or 2 mm. to 60 cm. or more in length.

Family Volvocaceae

Vegetative cells ciliated, solitary, or aggregated into colonies (coenobia), always free-swimming; popagation by zoospores and cell-fission; generation isogamic or heterogamic.

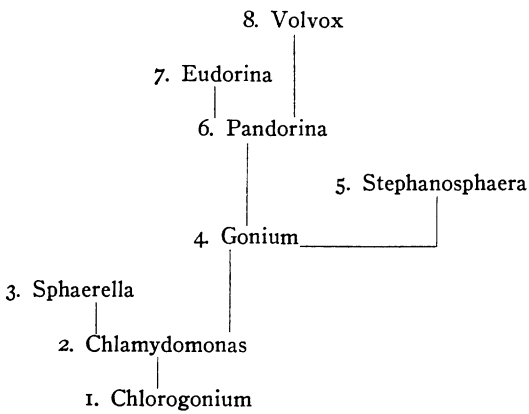
It may be doubted whether the organisms here included properly belong to the vegetable kingdom.

Key to the Genera.

A. Organisms strictly unicellular,
- I. Gelatinous sheath apparently wanting, 1. *Chlorogonium.*
- II. Gelatinous sheath evident,
  - a. Sheath close-fitting, at least on one side, 2. *Chlamydomonas.*
  - b. Sheath loose, 3. *Sphaerella.*

B. Organisms in colonies,
- I. Cells in one plane, cilia on one side,
  - a. Colonies strictly tabular, surrounded by a close-fitting gelatinous sheath, 4. *Gonium.*
  - b. Colonies surrounded by a loose, oval or spherical gelatinous sheath, 5. *Stephanosphaera.*
- II. Colonies oval or spherical with cilia on all sides,
  - a. Of 16 or 32, closely aggregated cells (colonies solid), 6. *Pandorina.*
  - b. Of 32 (rarely 8 or 16) closely aggregated cells (colonies hollow), 7. *Eudorina.*
  - c. Of very many cells (several hundred or more, colonies hollow), 8. *Volvox.*

The following scheme shows the mutual relationships of the genera.



1. *Chlorogonium* Ehrenberg. Vegetative cells fusiform, green, solitary, biciliate at the long-acuminate anterior end, and surrounded by a very thin, closely-fitting gelatinous sheath (apparently wanting); propagation by internal division into four to eight zoospores; generation by the union of ciliated isogametes or heterogametes which form (sixteen to thirty-two) by the internal division of a mother cell.—Species one, in fresh waters. Cells about $30 \times 8\,\mu$.

2. *Chlamydomonas* Ehrenberg. Vegetative cells, spherical, oval, or sub-cylindrical, green, solitary, with two to six cilia, and surrounded by a thin sheath which is closely-fitting, at least at one side; propagation by internal division into zoospores, or "palmella" cells; generation by the union of ciliated isogametes (or ciliated, or non-ciliated heterogametes) which form (eight to sixteen) by the internal division of a mother cell.—Species few in fresh and salt waters. Cells about 8 to $40\,\mu$.

3. *Sphaerella* Sommerfeldt. (*Haematococcus* Agardh.) Vegetative cells subglobose, green or often bright red, solitary, with two or more cilia, and surrounded by a loose gelatinous sheath, these cells sometimes without cilia and with thick walls (resting cells); propagation by internal division into zoospores or "palmella" cells; generation by the union of ciliated isogametes, which form in great numbers in mother cells.—Species few in fresh and salt waters as well as upon ice and snow ("Red Snow"). Cells from 7 to $80\,\mu$.

4. *Gonium* Mueller. Vegetative cells globose or slightly angular,

biciliate, green, four or sixteen aggregated into a quadrangular, tabular family consisting of a single layer which is surrounded by a very close-fitting gelatinous sheath; propagation by the repeated subdivision of the cell-contents and the formation of minute families which are set free by the rupture of the wall; generation unknown.—Species two, free-swimming by an irregular, rolling motion, in fresh water ponds and pools. Cells from 5 to 20 μ in diameter, the families from 20 to 90 μ.

5. *Stephanosphaera* Cohn. Vegetative cells fusiform or cylindrical, biciliate, green, eight, loosely arranged somewhat parallel to each other in a loose hyaline spherical envelope: propagation by successive subdivision of the cell-contents and the formation of minute two- to eight-celled families; generation by the union of ciliated isogametes, which form by the division of the cells (four to thirty-two in each) within the common sheath.—Species one, free-swimming by a rolling motion, in fresh waters. Cells from 7 to 12 μ in diameter, the families from 30 to 60 μ.

6. *Pandorina* Bory. Vegetative cells globose or subglobose, biciliate, green, sixteen (rarely thirty-two) closely aggregated into a globose family surrounded by a hyaline envelope: propagation by the successive subdivisions of the cell-contents and the formation of minute families; generation by the union of ciliated isogametes or heterogametes, which are formed (sixteen or thirty-two) in each cell. Species one, free-swimming by a rolling motion, in quiet fresh waters. Cells 6 to 15 μ in diameter, the families from 25 to 200 μ.

7. *Eudorina* Ehrenberg. Vegetative cells globose, biciliate, green, thirty-two (rarely eight or sixteen), loosely aggregated in the periphery of a globose, hollow family, surrounded by a loose hyaline envelope; propagation by the successive subdivision of the cell contents, and the formation of minute families; generation by the union of long-pyriform, biciliated androgametes (sixty-four, formed by the division of one of the cells) with the globular, biciliated gynogametes (one, formed by the transformation of one of the cells).—Species one, free-swimming by a rolling motion, in quiet fresh waters. Cells from 5 to 24 μ in diameter, the families from 45 to 200 μ.

8. *Volvox* L. Vegetative cells globose or subglobose, biciliate, green, closely arranged (several hundreds to many thousands) in the periphery of a globose hollow family: propagation by the suc-

cessive sub-division of the cell-contents of a few cells, and the formation of minute families; generation by the union of club-shaped, biciliate androgametes (eight to 256, formed by the division of specialized cells) with globular, non-ciliated gynogametes (each formed by the transformation of a specialized cell).—Species three, free-swimming by a rolling motion, in quiet fresh waters. Cells from 2 to 6 or 7 μ in diameter, the families varying from 50 μ to 600 or 800 μ.

OTHER CLASSIFICATIONS OF THE GREEN ALGAE

The recent publication of the fourth edition of Engler's Syllabus der Pflanzenfamilien (1904), Blackman and Tansley's Revision of the Classification of the Green Algae (1903), West's Treatise on the British Freshwater Algae (April, 1904), and Oltmanns's Morphologie und Biologie der Algen (July, 1904), makes it possible to show in parallel columns the different systems of classification which they employ (see table). It will be seen that there is little agreement as to the taxonomic grade of the groups. There is even less agreement as to subdivision of groups, and least of all as to their arrangement.

In comparing these four systems it must not be forgotten that Engler's and Oltmanns's are general, including all algae, while that of Blackman and Tansley includes the green algae only (excluding the Diatoms and Charales)), and West's is confined to British freshwater algae (including the Diatoms, but not Charales). Engler sets off the Zygophyceae, Chlorophyceae and Charales as "branches" (Abteilungen) coördinate with Archegoniates (Embryophyta Asiphonogama), and Spermatophytes (Embryophyta Siphonogama). These he subdivides into classes, and the latter directly into families. Thus the class Bacillariales contains the single family Bacillariaceae, including all the Diatoms. West divides Bacillariaceae (as a class) into two orders, and these into no less than fifteen families. Blackman and Tansley group the green algae into four classes upon a single character, namely, the cilia on the zoospores and gametes, resulting in four parallel lines (classes). Their "series" are equivalent to "orders" in other systems. In West's system the old group Chlorophyceae is nearly the same as Engler's, but with the addition of the Conjugatae. Oltmanns's system, as far as it can be made out from the first volume ("Spezieller Teil"), is much like

West's, and includes three larger groups (classes?), the second and third divided into lower groups (orders?) which in turn are divided into families. Oltmanns does not use the terms "class" and "order" in the volume at hand, and for this reason parentheses are used in the table.

TABLE SHOWING OUTLINES OF CLASSIFICATIONS OF GREEN ALGAE

I. (Engler)	III. (West)[1]	V. (Bessey)
Branch ZYGOPHYCEAE Class *Bacillariales* Class *Conjugatae* Branch CHLOROPHYCEAE Class *Protococcales* Class *Confervales* Class *Siphonales* Branch CHARALES Class? *Characeae*	Class *Bacillariacae* Order Centricae Order Pennatae Class *Heterokontae* Order Confervales Class *Chlorophyceae* Order Protococcoideae Order Conjugatae Order Siphoneae Order Cladophorales Order Microsporales Order Schizogoniales Order Ulvales Order Chaetophorales Order Oedogoniales	Class *Chlorophyceae*[2] Order Protococcoideac Fam. Pleuroccaceae Fam. Protococcaceae Fam. Hydrodictyaceae Fam. Volvocaceae? Order Confervoideae Fam. Ulvaceae Fam. Ulotrichaceae Fam. Chroolepidiaceae Fam. Cladophoraceae Fam. Pithophoraceae Fam. Sphaeropleaceae Fam. Cylindrocapsaceae Fam. Oedogoniaceae
II. (Blackman & Tansley)	**IV. (Oltmanns)**	Order Conjugatae Fam. Zygnemataceae Fam. Desmidiaceae Fam. Bacillariaceae
Class *Isokontae* Series Protococcales Series Siphonales Series Ulvales Series Ulotrichales Class *Stephanokontae* Class *Akontae* Series Desmidiales Series Zygnemales Class *Heterokontae* Series Chloromonadales Series Confervales Series Vaucheriales	(Class) *Heterocontae* (Class) *Acontae* (Order) Conjugatae (Order) Bacillariaceae (Class) *Chorophyceae* (Order) Volvocales (Order) Protococcales (Order) Ulotrichales (Order) Siphonocladiales (Order) Siphonales (Order?) Charales	Order Siphoniaceae Fam. Valoniaceae Fam. Botrydiaceae Fam. Vaucheriaceae Fam. Phyllosiphonaceae Fam. Bryopsidaceae Fam. Caulerpaceae Fam. Codiaceae Fam. Dasycladiaceae

The class Stephanokontae of Blackman and Tansley includes the single family Oedogoniaceae. In their class Heterokontae the first

[1] The sequence is reversed here so as to facilitate comparison with the other systems. West begins with higher forms and proceeds from these to lower forms.

[2] Here including holophytic families only.

"series" purposely includes flagellate animals (*Chloramoeba, Vacuolaria, Chlorosaccus* and *Chlorobotrys*) "since they represent the primitive organisms possessing Heterokontan characters, from which the next two series have been derived." The series Confervales includes such organisms as *Chlorothecium, Mischococcus, Ophiocytium, Conferva* (of Lagerheim) and *Botrydium.* These authors include *Vaucheria* in a third series, thus widely separating this genus from other Siphonales (in the class Isokontae). This separation is not followed by either West or Oltmanns, who recognize the class Heterokontae as including the Confervales only.

On looking over the outlines of these four systems, that of Blackman and Tansley strikes one as quite the most radical. In order to be understood the position of the authors as stated in their introduction must be borne in mind, as follows: "The most fundamental of these modern conceptions is that which proposes to regard the Algae as consisting of a number of natural classes, phylogenetically independent of one another, more or less parallel in evolution, and each derived separately from the Flagellata. . . . These parallel classes are generally to be distinguished from one another by cytological characters, and more especially by differences in the organization of the zoospore, which is held to retain, throughout each class, most of the characteristics of its primitive flagellate ancestor. The most conspicuous of these differentiating characteristics of the zoospore are the nature of the assimilatory pigments, the character of the chromatophore, and the arrangement of the flagella."

RELATIONSHIP OF THE GREEN ALGAE TO THE LOWER ANIMALS

The relationship of the green algae to lower animals has been suggested by many biologists. The similarity, amounting to essential identity, of the nuclear structure of plants and animals suggests their common origin. It is probable that since green plants are capable of holophytic existence, they came into existence before animals, few of which are able to live in the absence of organic food matter. It is true that attempts have been made to derive the green algae from the Flagellata, the latest being that of F. F. Blackman and A. G. Tansley in the *New Phytologist* (I, 22; 1902). These authors say, "According to modern views the Green Algae are derived phylogenetically from the Flagellata, a group of unicellular

organisms usually reckoned by zoologists as belonging to the Protozoa, and containing a very varied assemblage of forms, many of which show a mixture of animal and plant characters. The Volvocaceae naturally connect the Green Algae with the Flagellata, and on account of their motility and the general resemblance of their body to the Flagellate type, are often included in the latter group. Klebs, however, showed (Flagellatenstudien, *Zeit. f. wissen. Zool.*, 1892) that a great consensus of characters united the Volvocaceae with the Green Algae, and separated them from all other organisms of the Flagellate type, and the case for their separation is in our opinion overwhelming. It will be convenient to insert here the characters of the Flagellata for comparison with the diagnosis of the Volvocaceae given above.

FLAGELLATA. Body unicellular, or a colony of cells, cell uninucleate, with a thick or thin external layer of protoplasm, the *periplast,* in which amoeboid changes of form may take place. Outside this a non-living investment of the cell is frequently present; it may present the most varied form and is often not closely adherent to the body. Specialized anterior end of clear protoplasm bearing one or more flagella. One or more contractile vacuoles are present. Organism always remaining capable of movement. Nutrition either holozoic (solid food being taken by pseudopodia, through a specialized mouth, or otherwise) saprophytic or holophytic. In the last case the chromatophores are green or yellow and may take the form of bands, plates or discs. True pyrenoids entirely absent. Paramylon, leucosin, or a fatty oil the visible anabolites. Starch entirely absent. Reproduction by simple longitudinal division, usually beginning at the anterior end of the body. Individual always capable of forming resting cysts. Gamogenesis apparently entirely absent."

The foregoing diagnosis which is given on the theory that the Flagellata are animals is essentially like that given by Engler (Syllabus der Pflanzenfamilien, Vierte Auf.), who includes them among plants. For myself I cannot accept the Flagellata as a plant group, and while admitting their relationship to plants, would relegate them to the animal kingdom. With them, I am inclined to think, should go the Volvocaceae, which apparently constitute a connection between the two kingdoms. Instead of deriving plants from animals through the Volvocaceae and Flagellata, I should reverse the sequence and derive animals from plants. From *Protococcus* the passage is an easy one to *Chlamydomonas,* from which the passage is equally easy not only to *Pandorina* and *Volvox,* but also to the true Flagellata, and from the latter the way is clear to other animal

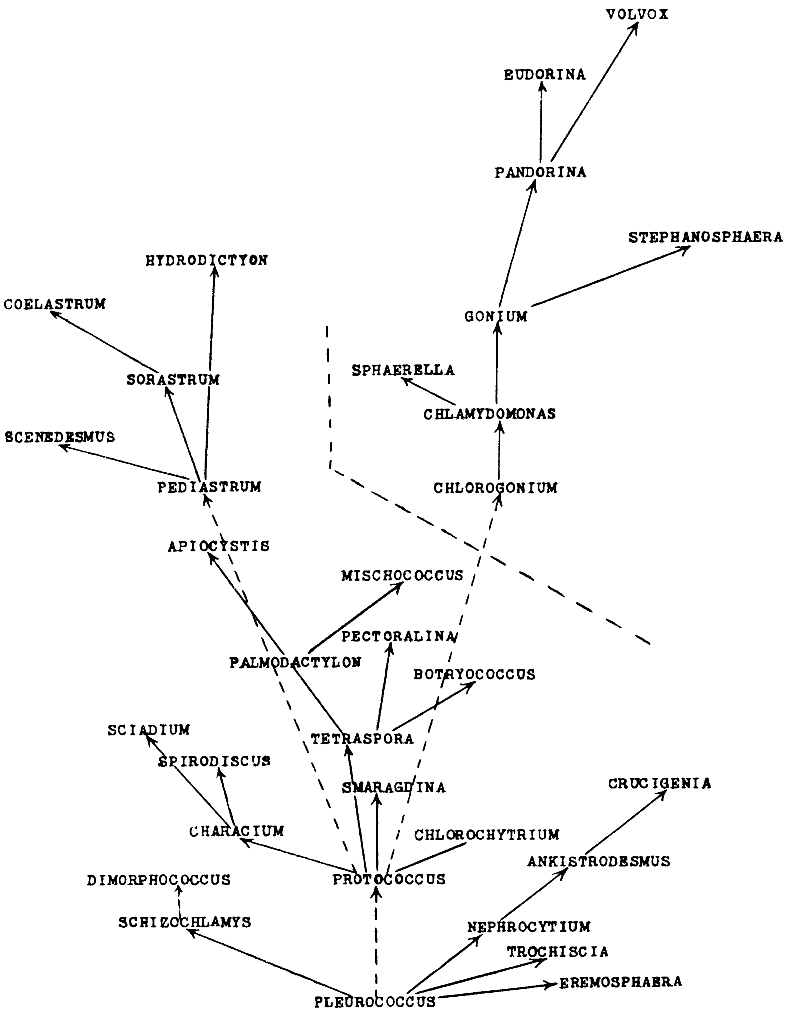
forms, lower and higher. Of course it is not a matter of very great consequence whether we place these equivocal organisms in this or that kingdom. It is true, however, that if we allow the Volvocaceae to remain among plants we find it quite difficult to exclude " a whole menagerie of organisms whose zoology is orthodox to a degree " as Doctor Thaxter very pointedly remarks (*Bot. Gaz.*, XXXVII, 405; 1904). Any assignment of these organisms to either kingdom seems to do violence to some by separating them from others with which they are certainly related, but my own judgment is that less violence is done when we draw the boundary line between the two kingdoms so as to exclude Volvocaceae, Flagellata, Dinoflagellata, and Silicoflagellata from the vegetable kingdom. In passing we may note the growing acquiescence of botanists in the exclusion of the slime animals (Myxozoa, Myxomycetes) from the vegetable kingdom. In like manner we may soon become accustomed to look for the organisms associated with the Flagellata in the animal kingdom.

EXPLANATION OF PLATE XII

CHART TO SHOW THE MUTUAL RELATIONSHIPS OF THE GENERA OF PROTOCOCCOIDEAE

The dotted line at the right indicates the boundary between the vegetable and the animal kingdoms, in accordance with the views set forth in the preceding pages.

PLATE XII


VOLVOX
EUDORINA
PANDORINA
STEPHANOSPHAERA
HYDRODICTYON
COELASTRUM
GONIUM
SPHAERELLA
SORASTRUM
CHLAMYDOMONAS
SCENEDESMUS
PEDIASTRUM
CHLOROGONIUM
APIOCYSTIS
MISCHOCOCCUS
PECTORALINA
PALMODACTYLON
BOTRYOCOCCUS
SCIADIUM
TETRASPORA
SPIRODISCUS
SMARAGDINA
CRUCIGENIA
CHARACIUM
CHLOROCHYTRIUM
ANKISTRODESMUS
DIMORPHOCOCCUS
PROTOCOCCUS
SCHIZOCHLAMYS
NEPHROCYTIUM
TROCHISCIA
EREMOSPHAERA
PLEUROCOCCUS